PART I. SYNOPSIS

Within the broad objectives of the agreement several specific areas of investigation were chosen. Most of these involved studies that had something to do with the fresh water portion of the life cycle of king salmon.

LIFE HISTORY OF KING SALMON

The literature, both scientific and popular, on king salmon is voluminous. Chinook salmon are commonly called king salmon, spring salmon and also tyee. King salmon are anadromous, that is they spend most of their life in the ocean but they ascend fresh water rivers and streams to spawn. The fish typically spawn in the fall with a considerable range from late summer to early winter. The spawning act is similar to other salmonids. They dig nests, called redds, into the river gravels. Eggs are spawned, fertilized, and buried as the redd is being built. The eggs hatch after about two months and the young live in the gravel on the food provided in the yolk sac. In late winter or early spring the fish emerge as fry. The length of time that the fry spend in fresh water varies considerably. Most fry begin to migrate downstream immediately, but others remain to migrate in late spring and early summer. A few young salmon remain in fresh water almost a year to migrate as yearlings. Not much is known of the estuarine life of the salmon. In the Feather River from two to six, usually three or four, years later the salmon return from the ocean as adults to spawn.

FALL RUN ADULT KING SALMON ENUMERATION

We began our studies of salmon in the Feather River with the enumeration of adult fish. This is most appropriate because successful maintenance of a large run of salmon is the best indication that Oroville Dam operations are compatible with salmon.

Our best estimates of the size of the runs from dead fish counts, made for a number of years prior to Oroville Dam completion, varied between 11 and 86 thousand salmon. We conclude that under proper management a run of from 40 to 60 thousand adult salmon should be expected each year.

During our investigation, as indicated fish population estimates were made by enumeration of salmon carcasses. In some years we compared this method of enumeration with several other techniques.

Since completion of Oroville Dam in 1968, salmon runs have fluctuated between 18,000 and 74,000 fish. Population levels for six of the seven years were greater than 40,000 fish (Table 1).

These counts indicate that:

1. From 1968 to 1972 the population levels were high and these excellent runs were produced from stocks raised under dam construction conditions. Therefore, dam construction had no serious effect on fall run salmon.
2. From 1973 to 1975 the fall run population level remained high. These adult returns came from eggs spawned and hatched during ordinary Oroville Project operation. Our conclusion is that ordinary operations do not have serious effects in fall run salmon abundance.
3. Overall, the Oroville Project operations have maintained and possibly increased salmon abundance.

AVAILABLE GRAVEL STUDY

One important control that Oroville Project operation has upon spawning king salmon is the quantity of gravel inundated by the river. Within limits, river flow determines the area of spawning gravel available to the salmon.

Prior to Oroville Project completion the Department of Fish and Game conducted an available gravel study and estimated the 1,700 cfs was the minimum flow acceptable to provide maximum protection of salmon spawning habitat. During our study we conducted a similar investigation to verify the earlier work.

The 1969 study confirmed that the earlier 1,700 cfs flow figure was sufficient as a minimum flow level. The results of this investigation, based on observation of three riffle areas were that 2,000 cfs was the preferred flow. However, the difference in gravel area made available by the additional 300 cfs was only six percent. This difference is within the experimental error of the methods used in estimating gravel area, and no proposal was made to change the minimum flow criteria agreed to in the "contract".

During 1974 we planned a similar available gravel survey to determine if any significant changes in spawning area had occurred during five years of Oroville Project operation. Unfortunately, exceptionally high run-off in the spring prevented a study then. In the fall, extraordinarily high flows were maintained to lower Oroville Lake for repair and maintenance of dam structures. Again we would not conduct a study.

GRAVEL QUALITY STUDY

It was assumed that gravel quality in the Feather River was excellent prior to the Oroville Project. There was concern that this quality had deteriorated during dam construction. It was postulated that large amounts of fine sediments, washed into the river from adjacent borrow areas, had reduced the value of river gravels for salmon spawning.

Gravel quality requirements of salmon are well known. Primary measurements of this quality are sediment size distribution. Because large amounts of fines from siltation reduce gravel permeability and reduce oxygen supplies to the spawning beds, as well as measurements of gravel sediment size distribution permeability, intergravel oxygen, and intergravel water temperature were taken.

We measured these several factors in riffles throughout the spawning area and found that Feather River gravels are still good to excellent. There was an expected deterioration of quality with increased distance downstream from Oroville. We conclude that there was no apparent loss of gravel quality caused by Oroville Dam construction. Further, we cannot demonstrate that any gravel deterioration has yet occurred because of Oroville Project operations.

EGG SURVIVAL STUDY

The expected result of a large population of spawning salmon, an abundance of available gravel, and gravel of good quality is a high percent survival of the spawned eggs. If survival is low then either our assumptions about available gravel or gravel quality were incorrect or some other factor, e.g., too many salmon, disease, parasites, pollution might be suspected. Egg survival statistics, then, are an important barometer of stream conditions.

We used egg survival studies primarily as a biological check upon gravel condition as well as confirmation of absence of other mortality factors. Instead of the infrequent investigation schedule agreed upon in the original work outlined, we examined eggs from salmon nests each year of our study.

The results were that survival was good to excellent in the high flow river area and was generally poor in the low flow reach of the river. Survival in the high flow area exceeded 70 percent every year. In contrast, egg survival frequently was as low as 40 percent in the low flow reach.

Gravel quality has not deteriorated in this low flow area. On the contrary, the gravel here is the best in the entire river. We conclude that the low survival rates are a result of Oroville Project operations and are caused by too many adult salmon spawning in a limited gravel area.

One year, in an investigation associated with the Egg Survival Study, we found that a significant percentage of the salmon nests were affected by a large reduction of flow during the incubation period of eggs and larvae. Although operating within the existing agreement, this drop in flow of 900 cfs resulted in egg mortality in about five percent of the redds.

YOUNG SALMON OUTMIGRATION STUDY

Each year we estimated the number of young salmon that migrated from the spawning area. We found that during high run-off years the outmigration peaked in mid-January. In low water years the peak was not reached until mid-February. In both types of water year outmigration began in mid-December but during wet years the majority of the outmigrants were past Live Oak by the end of January. In low water years the bulk of the outmigrants were not out and past Live Oak until the first week in March. In all years, the average size of fish did not vary more than one or two millimeters during the peak migration period.

The timing of downstream migration may be a very important factor in fish survival as river discharge, water temperature, and turbidity vary widely seasonally. Available environmental data were examined to find meaningful relationships between environmental factors at the time of downstream migration and subsequent return of adult salmon three and four years later. We were able to find some weak correlation between return of adults in any year with flow conditions during the outmigration period three and four years earlier. Because of the variable correlations from month to month no meaningful hypothesis could be developed. However, because of possible adult salmon enumeration error and unknown contribution of various year classes of salmon to adult return for any year, there might still be a relationship between flow during outmigration and return of adult salmon.

During several spring seasons we salvaged young salmon from large pools formed after reduction in river flow. Our study of this problem was inadequate in some respects but was sufficient to recommend some added flow reduction criteria from March through June of each year.

SPRING-RUN KING SALMON SURVIVAL

The behavior and environmental requirements of spring salmon are quite different from fall-run salmon. The majority of salmon in the Feather River are the fall-run type. That is, they return to the river from the ocean in late summer and early fall to spawn when river conditions become suitable. Spring-run salmon, however, begin to arrive in March. Most have arrived by the end of May.

Spring-run salmon need cool water to "hold" in during summer hot weather. Prior to Oroville Dam construction, these fish spent the hot summer months in the cool waters of the various forks of the upper Feather River. Now, the spring-run salmon are denied access to these waters and must spend the summer in the lower river, principally in the area immediately below the Fish Diversion Dam to the fish hatchery at Oroville.

From pre-Oroville Dam fish counts we expected a spring-run king salmon population of about 2,000 adult fish. The direction of our studies was to determine if post-project river conditions were sufficient to maintain this resource. Our study included a weekly examination of the river during the summer months in search of dying or dead adult salmon.

During our river surveys we found very few spring-run salmon carcasses. Our conclusions are that the summer temperature regime in the vicinity of the Feather River Fish Hatchery is sufficient to allow excellent survival of spring-run salmon.

We must state, however, that the fish populations we have observed so far have been only several hundred fish. We do not know if the limited habitat below the hatchery will continue to provide good survival with expected future runs of several thousand fish.

AMERICAN SHAD AND STRIPED BASS STUDIES

Like the salmon, American shad and striped bass are anadromous, i.e., they have most of their life cycle in the ocean but return to freshwater to spawn. Unlike the salmon, however, these fish do not dig nests (redds). Instead, they broadcast their eggs freely in the water, usually near the surface, where the eggs are fertilized. Striped bass eggs drift with river currents while American shad eggs tend to settle slowly to the bottom. Depending upon temperature, the eggs hatch in from five to ten days. Some of the small larvae are swept downstream and out of the river immediately. Others remain in the river until fall, when at a length of two to five inches they begin a migration to the ocean.

Our work agreement implied that a population estimate of these species would be initiated so that any relationship between fish population change and Oroville Project operations would be demonstrated. We soon determined, however, that such adult fish population studies were beyond the physical and monetary capabilities of our modest crew. Indeed, we might have spent our entire budget monies on these studies and still not adequately have covered the problem area. Therefore, we oriented our investigations toward a creel census to monitor angler fishing success, and toward a study of bass and shad egg and larvae relationships to Oroville Project Operations.

STRIPED BASS

While legal size bass were caught along the entire length of the river, our creel census of striped bass angler fishing success revealed that over 50 percent of the catches were made within five miles of the river mouth at Verona. Only in 1974 were significant numbers of legal bass caught in the upper river areas. We found that April river flow and river temperature were correlated with angler catch. Further, low catch rates can be expected whenever spring flows are less than 3,000 cfs.

During our egg and larvae sampling we did not find many striped bass eggs and never found any larvae. Some years no eggs were sampled. When we found eggs, they were from tows in the middle and lower reaches of the river. Only in 1974 were large numbers of eggs taken on more than one sample night.

Our conclusion is that only during 1974 was the Feather River an important waterway for striped bass spawning. It is, however, used every year as a nursery area for small striped bass and as a year-round habitat for a small population of large adult bass.

AMERICAN SHAD

Angler success for American shad was 1.5 fish per angler hour in 1968 and 1974. For the intervening years it was about half that value. Angler catch statistics are not the best indicators of fish population parameters in river environments. Often river conditions affect angling and mask any fluctuation in fish populations that may have occurred. Correlations of river flow and river temperature with angler success were not significant. Our conclusions from angler census are cautious and are simply that many fish are being caught and fishing is "fair".

We changed the direction and scope of the egg and larvae studies several times during our investigations. Some of the early techniques we used did not provide the kind of information sought. Our results from 1971 to 1974 egg and larvae collections are:

1. Oroville Project and river temperature:

   Because of the warming effect of the Thermalito Afterbay upon Feather River water, temperatures preferred by shad for spawning first occur in early May, about one month earlier than they historically used to.

2. American shad eggs:

   a. Shad that spawn in the early May period described above have a higher egg survival than do later spawners.

   b. Seasonal peaks in spawning are related to water temperature. The earliest peak follows the first occurrence of the 60° - 70° water temperature. Later peaks closely follow temperature peaks and the duration of the preferred temperature range.

   c. Daily fluctuations in egg abundance are also temperature related. Changes in water temperature of more than three degrees will cause the intensity of spawning to increase or decrease in the same direction as the temperature change.

3. American shad larvae:

   a. Shad larvae abundance peaks during the month of June.

   b. Peaks of larvae abundance follow periods of high egg survival rates and peaks of egg abundance 10 to 15 days prior to larvae sampling.

4. Outmigration of small shad:

   a. Unlike behavior of small shad on the east coast, river temperatures near 15.5°C (60°F) do not trigger outmigration. On the contrary, our shad migration is nearly complete before the river reaches the 15.5°C (60°F) level.

   b. Outmigration is virtually over by mid-October.

RESIDENT FISH

The Feather River contains a variety of game fish and several kinds of nongame fish. It was assumed that post-project conditions would be satisfactory for the game fish but it was possible that conditions would be better for the nongame fish such as carp, squawfish, and hardheads.

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During 1968, resident fish were collected to determine species composition. These collections were again made during 1974 to determine any change. A year-round creel census was conducted each year since 1970 to evaluate the angler catch and angler success.

Angler success has been good for all years evaluated (catch per angler hour ranged from 0.12 to 0.24). White catfish comprised 67 percent of the angler's catch. The fishery for resident fish is small.

SYNOPSIS CONCLUSIONS

From our studies on king salmon we conclude that:

1. There was no reduction in the adult fall-run king salmon population due to the construction phase of Oroville Dam.
2. Adult fall-run salmon returns since completion of the Oroville Dam Project have been high and indicate that "ordinary" Project operation procedures do not decrease the abundance of adult salmon.
3. The 1,700 cfs low flow limitation is sufficient to provide enough spawning habitat to maintain salmon populations over drought or dry years (minimum required spawning flow during a dry year, April-July runoff under 55%, is 1,200 cfs).
4. Dam construction did not deteriorate gravel quality and present gravel conditions are good for natural propagation of king salmon.
5. Egg survival is good in the high flow portion of the river and very low in the low flow river reach.
6. Spawning habitat reduction brought about by the lowered flow in the low flow area causes redd super-imposition, crowding of salmon into less desirable spawning areas, and results in poor egg survival.

7. Time of peak outmigration of salmon fry is related to water flow. During high-water years peak outmigration occurs in mid-January. In low-water years the peak is in mid-February.

8. Depending upon the time during the spring, the size of the outmigration population of young salmon, and the magnitude of flow reduction, fluctuations of river flow may result in numbers of salmon trapped in pools adjacent to the river.

9. We conclude from the low mortality of adult spring-run salmon that river holding conditions for these salmon are excellent.

From our striped bass and American shad studies we conclude that:

1. The Thermalito Forebay-Afterbay complex warms the Feather River water to spawning temperatures almost one month earlier than the pre-project natural condition.

2. Highest egg survival is usually early in the spawning period.

3. Seasonal peaks in spawning intensity and day to day fluctuations in spawning intensity are related to water temperature.

4. Almost all large catches of young-of-the-year shad outmigrants were made when river temperatures were greater than 21.1°C (70°F).

5. Angler success for American shad four of the six years of our studies decreased almost 50 percent of the first year angler catch rate.

6. Only one year during the course of our investigation was the Feather River used as a spawning area for striped bass.

7. A significant positive correlation was found between striped bass catch rates and April river flow, and a significant negative correlation between catch rate and April river temperatures.

8. We conclude from regression lines generated from these correlations that April flows below 3,000 cfs result in poor striped bass runs (poor catch rates).

The conclusions from the resident fish study are:

1. The changes in water flow and water temperature in the Feather River since completion of the Oroville Project have not altered the number of fish species present since 1968.
2. We conclude that except for the Sacramento sucker and hitch, pre- and post-project population levels of resident fish are not significantly different.
3. The fishery for resident fish is an excellent fishery at present, with white catfish dominating the catch.

RECOMMENDATIONS

Although the population levels of king salmon have been high since completion and during seven years of operation of the Oroville Project some opportunities are available to help assure the continuance of these excellent runs.

1. Flow in upper reach of the Feather River (Pages 40-43)
   Flow lowered to 400 cfs in the upper reach of the river has concentrated salmon onto a limited amount of spawning area, forced some salmon to spawn in undesirable habitat and has resulted in poor egg survival. We recommend that each year, from October 15 through January 31, the 400 cfs flow be increased by 600 cfs for a total flow of 1,000 cfs. To be effective, such a flow increase would have to be preceded by a vegetation removal program on some of the riffles to eliminate the vegetative encroachment of the past seven years.
2. Flows during incubation of salmon eggs (Pages 74-76)
   Changes here are to ensure that eggs will not be dewatered by project operations. To do this we propose to change the flow schedule in the Operations Agreement (Append. I, Pg. 3-4, Para. 3) to read as follows:

During Period October 1 through November 15

Mean Flow (cfs)*	Fish Flow (cfs)
2,500 - 3,000	500 cfs < mean flow
3,000 - 3,500	" " " "
> 3,500	3,000

*Average release to Feather River for one hour period.

3. Flow During Outmigration of Young Salmonids (Pages 78-80)

Although our studies on stranding of small fish by receding or fluctuating spring river flows were inconclusive, we did opine that interim protection was indicated until the full significance of stranding was understood. We recommend extending the March 31 end of the 500 cfs limitation in flow-fluctuation (Appendix I, Contract, Para. 3C) until June 30. This would change the existing contract schedule which reads:

Flow	Control	Time Period
2,500 cfs	200 cfs in any 24 hour period	Year-round
2,500 - 3,500	500 cfs in any 24 hour period	Oct. 1 - March 31
> 3,500	None	Year-round

To read as follows:

Flow	Control	Time Period
2,500 cfs	200 cfs in any 24 hour period	Year-round
2,500 - 3,500	500 cfs in any 24 hour period	Oct. 1 to June 30
> 3,500	None	Year-round

4. Flows during upstream migration of American shad and striped bass (Pages 61-66)

Our studies revealed that during April and May correlations between water temperature and river discharge were significant. Further, striped bass catch rates in the mid-river area were significant with both April river flow and temperature. Very high but not significant correlations were also found between striped bass catch rates and May river flow and American shad catch rates and May river temperature.

The recommendation formulated from these investigations is to maximize spring flows. Whenever possible, April and May flow should be greater than 3,000 cfs. Every effort should be made to improve run-off predictions from snowpack in the watershed so that less reservoir storage will be required early in the spring. More water will then be available for April and May river flows.